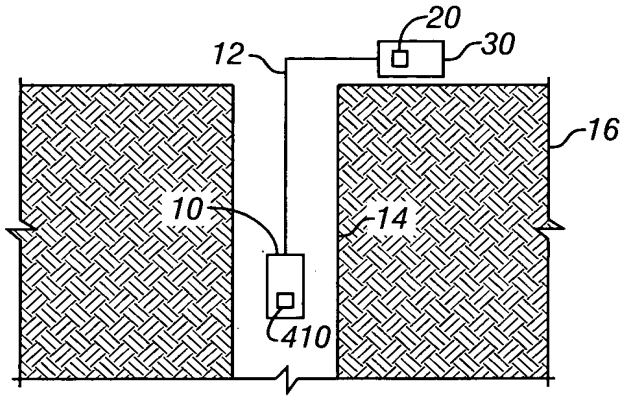

FIG. 1

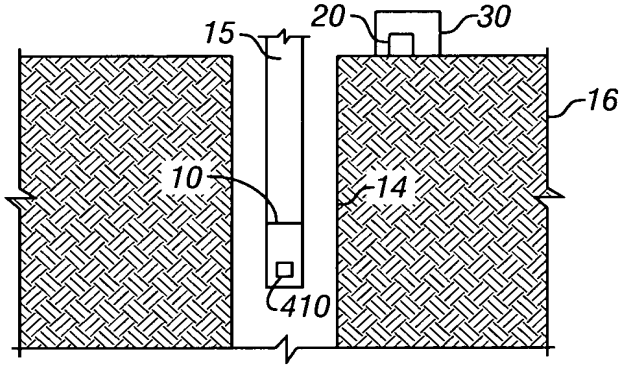

FIG. 2

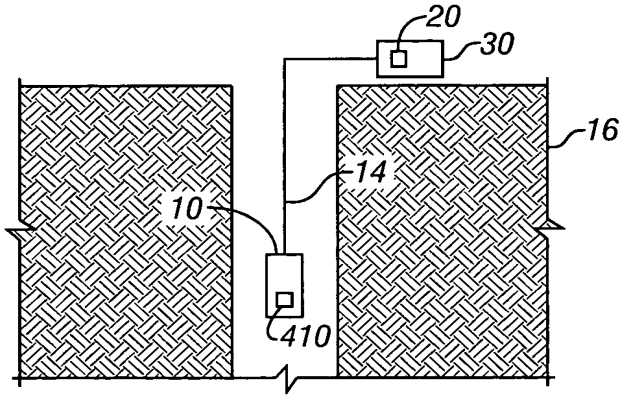

FIG. 3

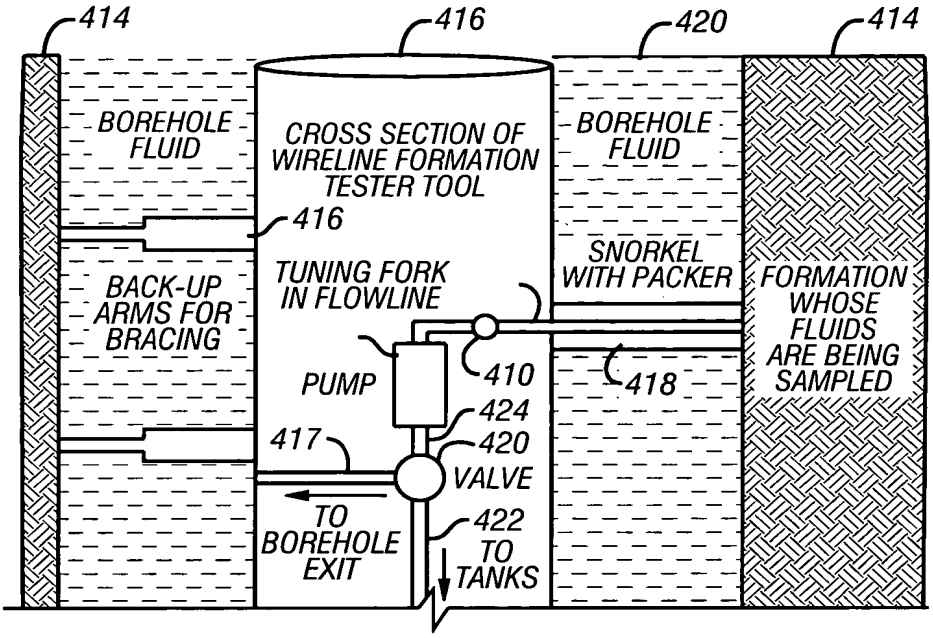
414
416
420
414
BOREHOLE FLUID
CROSS SECTION OF WIRELINE FORMATION TESTER TOOL
BOREHOLE FLUID
416
BACK-UP ARMS FOR BRACING
TUNING FORK IN FLOWLINE
SNORKEL WITH PACKER
FORMATION WHOSE FLUIDS ARE BEING SAMPLED
PUMP
410
418
424
417
420
VALVE
TO BOREHOLE EXIT
422
TO TANKS

FIG. 4

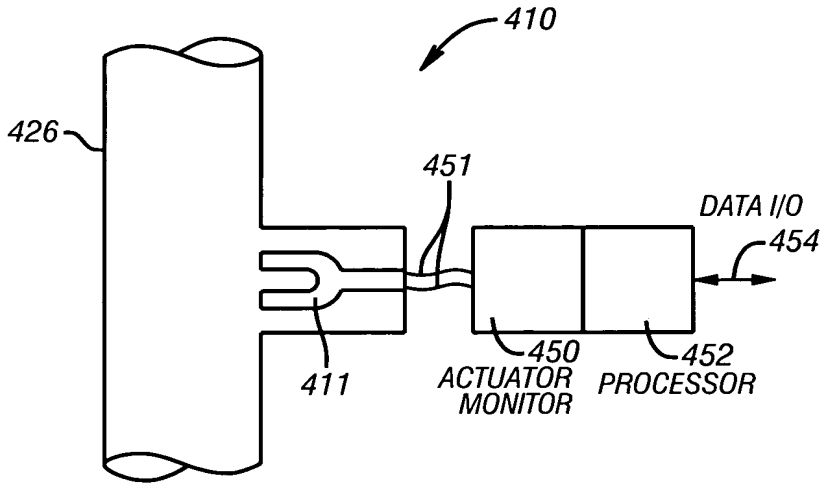
410
426
451
DATA I/O
454
411
450
ACTUATOR MONITOR
452
PROCESSOR

FIG. 5

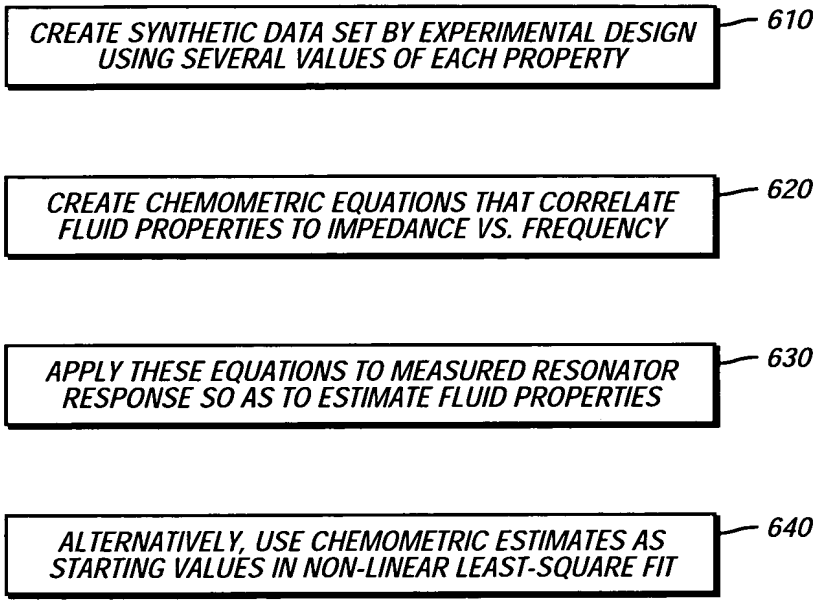
CREATE SYNTHETIC DATA SET BY EXPERIMENTAL DESIGN USING SEVERAL VALUES OF EACH PROPERTY
610
CREATE CHEMOMETRIC EQUATIONS THAT CORRELATE FLUID PROPERTIES TO IMPEDANCE VS. FREQUENCY
620
APPLY THESE EQUATIONS TO MEASURED RESONATOR RESPONSE SO AS TO ESTIMATE FLUID PROPERTIES
630
ALTERNATIVELY, USE CHEMOMETRIC ESTIMATES AS STARTING VALUES IN NON-LINEAR LEAST-SQUARE FIT
640

FIG. 6

Density

Regression Summary for Dependent Variable: g/cc (Synthetic Impedance Data.sta)
R= .99263581 R^2= .98532585 Adjusted R^2= .98514010
F(1,79)=5304.6 p<0.0000 Std. Error of estimate: .05053

	Beta	Std. Err.	B	Std. Err.	t(79)	p-level
Intercept			-10.0370	0.151558	-66.2254	0.00E+00
1/FLZD1	0.992636	0.013629	32.4538	0.445593	72.8328	0.00E+00

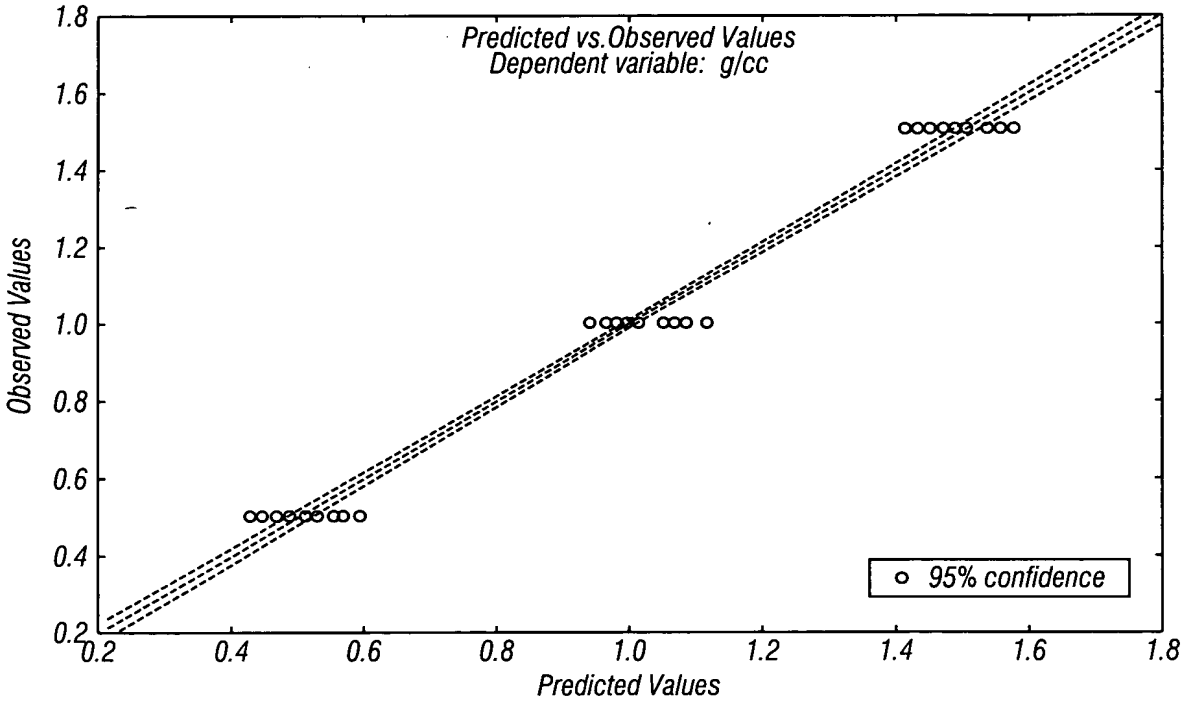

FIG. 7A

Density

Regression Summary for Dependent Variable: g/cc (Synthetic Impedance Data.sta)
R= .99909311 R^2= .99818705 Adjusted R^2= .99801321
F(7,73)=5741.8 p<0.0000 Std. Error of estimate: .01848

	Beta	Std. Err.	B	Std. Err.	t(73)	p-level
Intercept			-9.8709	0.08397	-117.550	0.00E+00
log(MaxD2)	0.158008	0.014018	0.0563	0.00500	11.272	1.121E-17
1/FMn_D1	0.714452	0.090942	23.2643	2.96161	7.856	2.62E-11
Cub_Min	0.728493	0.114662	100.5412	15.82487	6.353	1.61E-08
Cub_Avg	-0.738300	0.119953	-98.6059	16.02067	-6.155	3.67E-08
Min_D2	0.046837	0.012946	346.1813	95.68643	3.618	5.44E-04
1/FZD1	0.323058	0.090546	10.5622	2.96037	3.568	6.40E-04
Sqr_Min	0.106546	0.042182	3.0742	1.21708	2.526	1.37E-02

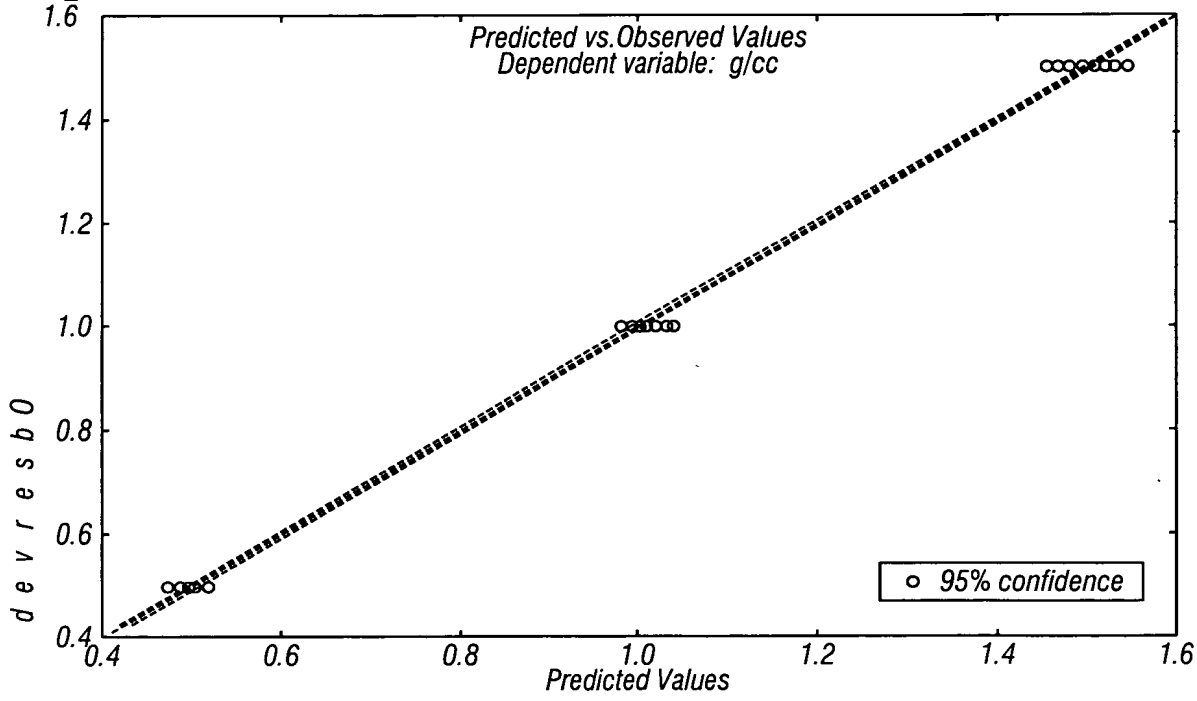

FIG. 7B

Density

Regression Summary for Dependent Variable: g/cc (Synthetic Impedance Data.sta)
R= .99970856 R^2= .99941721 Adjusted R^2= .99933396
F(10,70)=12004. p<0.0000 Std. Error of estimate: .01070

	Beta	Std. Err.	B	Std. Err.	t(70)	p-level
Intercept			-10.1349	0.04869	-208.130	0.000000E+00
log(MaxD2)	0.086694	0.006457	0.0309	0.00230	13.426	4.807740E-21
1/Min_D2	0.117544	0.009139	0.0000	0.00000	12.862	4.117729E-20
1/Max_D1	0.052427	0.006022	0.0000	0.00000	8.706	9.173387E-13
AvgD1	-0.047915	0.006490	-93.3906	12.64923	-7.383	2.489016E-10
1/FMn_D2	0.447306	0.082745	13.8455	2.56121	5.406	8.448959E-07
1/FMn_D1	0.446249	0.086245	14.5310	2.80834	5.174	2.086349E-06
1/Max	0.438247	0.106496	0.0261	0.00633	4.115	1.041422E-04
1/Min	-0.432207	0.108163	-0.0218	0.00547	-3.996	1.573313E-04
1/FLZD1	0.186323	0.047327	5.8908	1.49630	3.937	1.924973E-04
Log(Max)	0.071356	0.018739	0.1189	0.03122	3.808	2.976181E-04

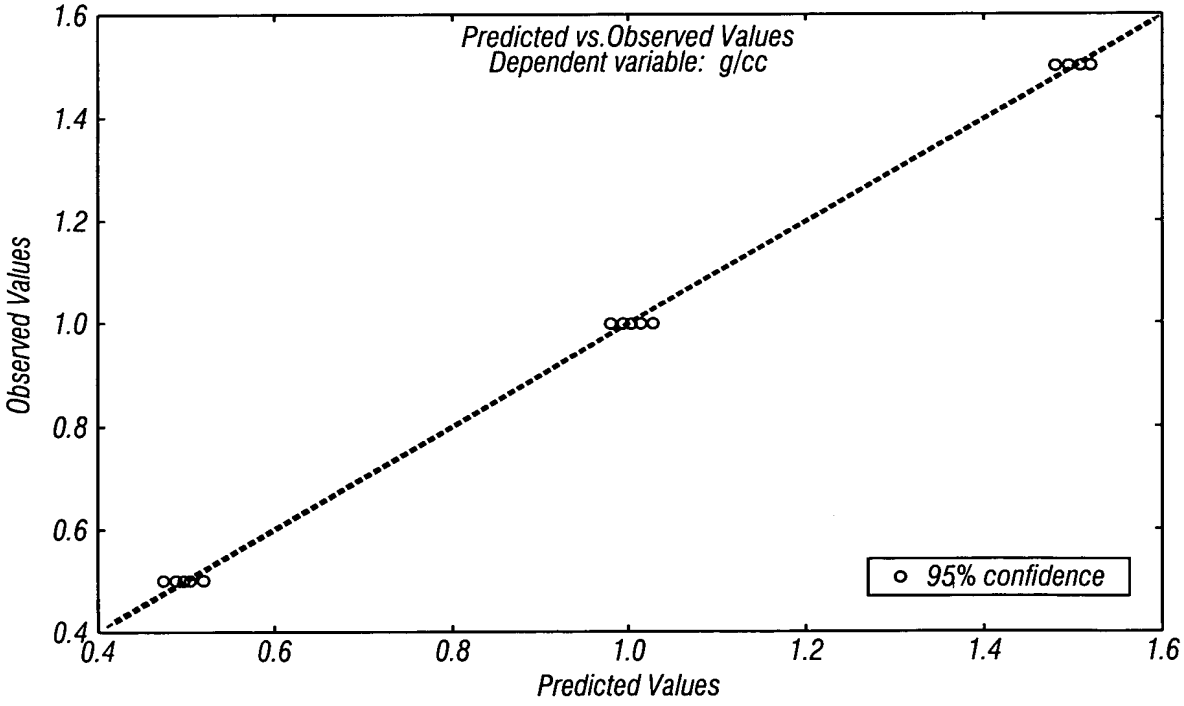

FIG. 7C

Viscosity

Regression Summary for Dependent Variable: cPs (Synthetic Impedance Data.sta)
R= .97696409 R^2= .95445882 Adjusted R^2= .95206192
F(4,76)=398.2 p<0.0000 Std. Error of estimate: .26970

	Beta	Std. Err.	B	Std. Err.	t(76)	p-level
Intercept			-15.694	0.9671	-16.2279	2.089853E-26
1/MinD2	-0.840896	0.035160	0.000	0.0000	-23.9160	4.151239E-37
FreqRMaxD1	0.506923	0.028371	5.662	0.3169	17.8679	6.229948E-29
MinD2	0.376456	0.033230	8268.363	729.8467	11.3289	5.432749E-18
Sqr_Min	-0.117944	0.024612	-10.112	2.1102	-4.7922	7.999455E-06

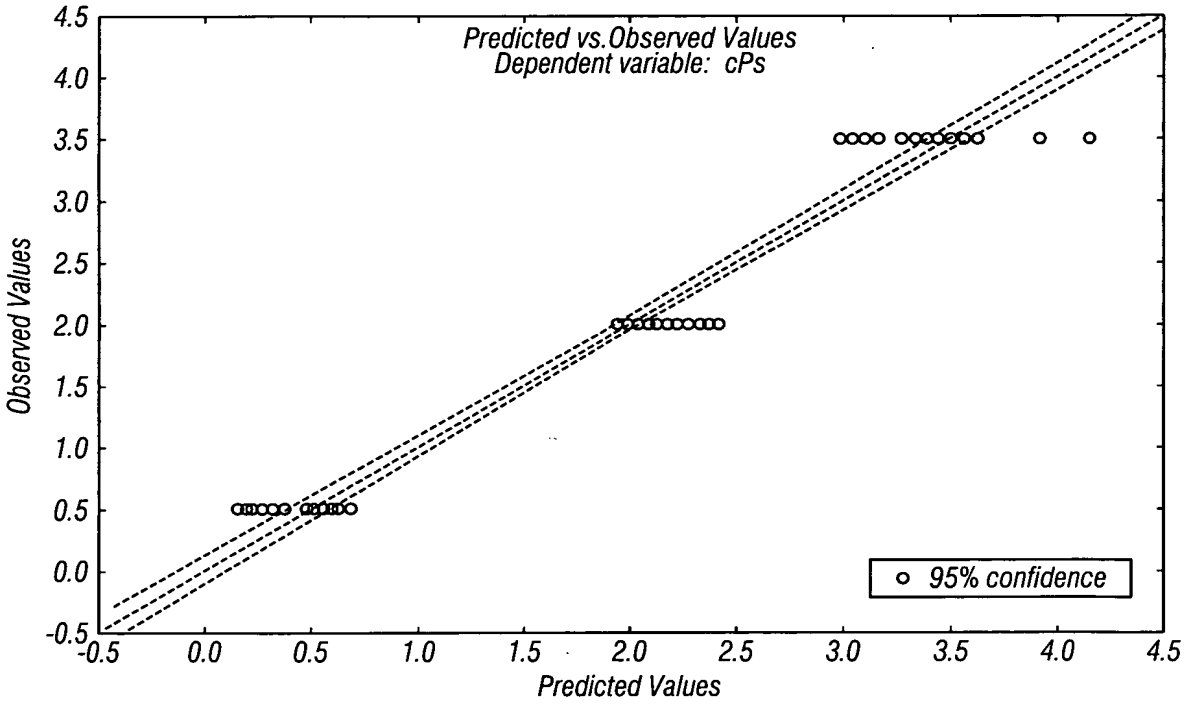

FIG. 7D

Viscosity

Regression Summary for Dependent Variable: cPs (Synthetic Impedance Data.sta)
R= .97873578 R^2= .95792372 Adjusted R^2= .95511863
F(5,75)=341.5 p<0.0000 Std. Error of estimate: .26096

	Beta	Std. Err.	B	Std. Err.	t(75)	p-level
Intercept			-17.653	1.214	-14.5445	1.57E-23
FreqLZeroD1	0.483355	0.029189	5.411	0.327	16.5596	9.17E-27
1/MinD2	-0.693825	0.058609	0.000	0.000	-11.8381	7.78E-19
Cub_Min	-0.169016	0.031429	-69.316	12.890	-5.3776	8.24E-07
MinD2	0.245608	0.065284	5394.464	1433.871	3.7622	3.32E-04
log(MaxD2)	-0.268470	0.097688	-0.284	0.103	-2.7482	7.50E-03

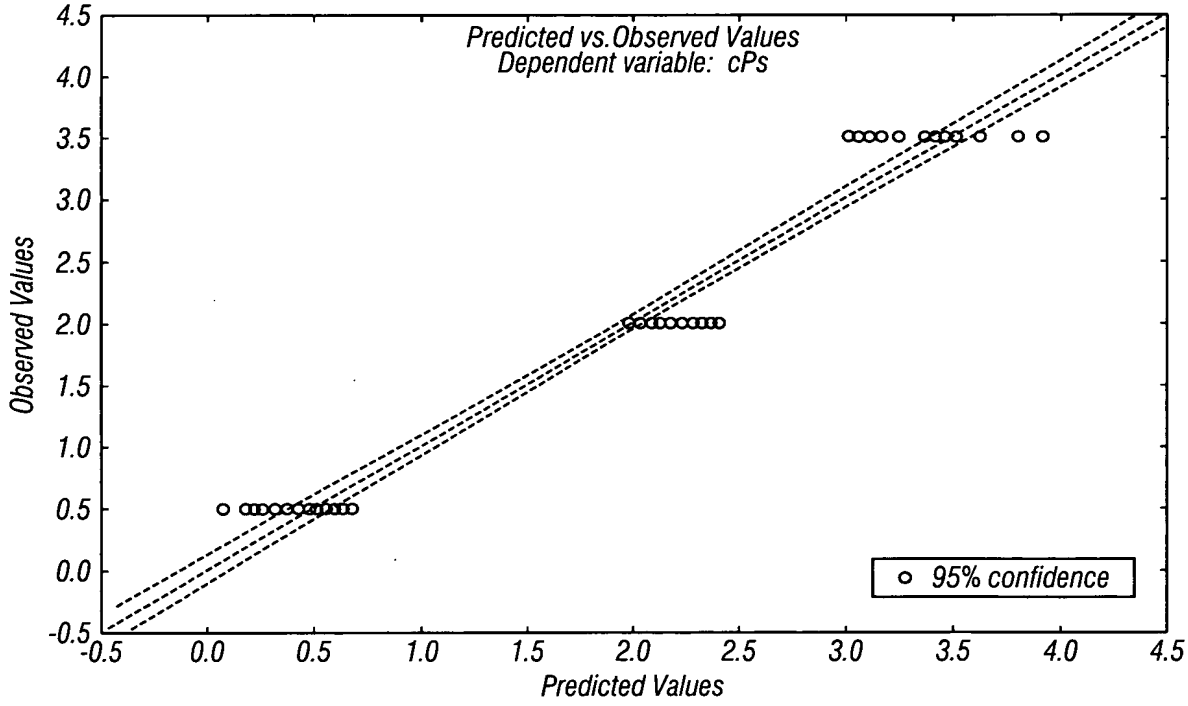

FIG. 7E

Viscosity

Regression Summary for Dependent Variable: cPs (Synthetic Impedance Data.sta)
R= .98468409 R^2= .96960276 Adjusted R^2= .96757627
F(5,75)=478.47 p<0.0000 Std. Error of estimate: .22181

	Beta	Std. Err.	B	Std. Err.	t(75)	p-level
Intercept			-12.938	0.8918	-14.5075	1.813627E-23
1/MinD2	-0.691176	0.043747	0.000	0.0000	-15.7994	1.434065E-25
PK	0.368418	0.029871	250.435	20.3047	12.3338	1.005152E-19
log(MaxD2)	-0.368199	0.043609	-0.390	0.0462	-8.4431	1.709891E-12
Cub_Min	-0.131400	0.023774	-53.889	9.7499	-5.5272	4.512895E-07
P27_D2	0.128036	0.028700	3078.767	690.1188	4.4612	2.817552E-05

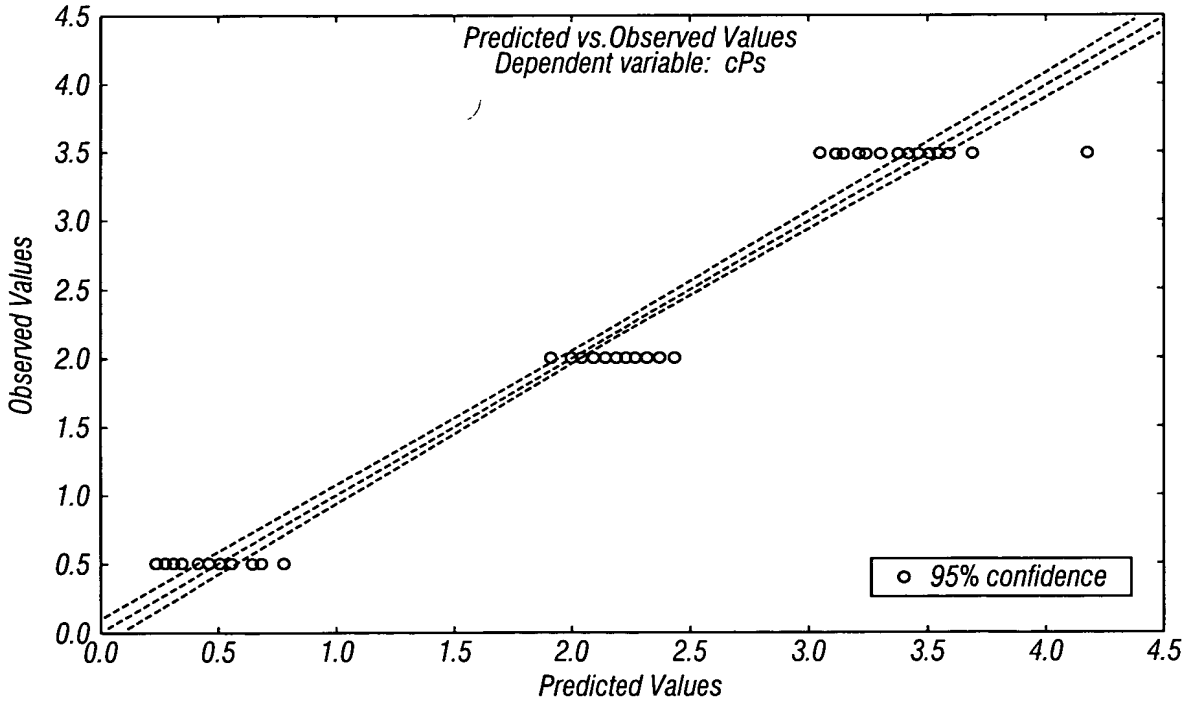

FIG. 7F

Dielectric Constant

Regression Summary for Dependent Variable: Dielectric (Synthetic Impedance Data.sta)
R= .99511668 R^2= .99025720 Adjusted R^2= .98974442
F(4,76)=1931.2 p<0.0000 Std. Error of estimate: 1.1857

	Beta	Std. Err.	B	Std. Err.	t(76)	p-level
Intercept			-9.15	0.581	-15.7513	1.206053E-25
AvgD1	1.37132	0.054288	75492.69	2988.616	25.2601	1.029444E-38
Sqr_Max	-1.46607	0.108461	-1157.11	85.604	-13.5170	6.567799E-22
Cub_Avg	4.64294	0.680918	17514.38	2568.600	6.8187	1.924593E-09
Cub_Max	2.46760	0.623626	-8978.25	2269.034	-3.9589	1.693159E-04

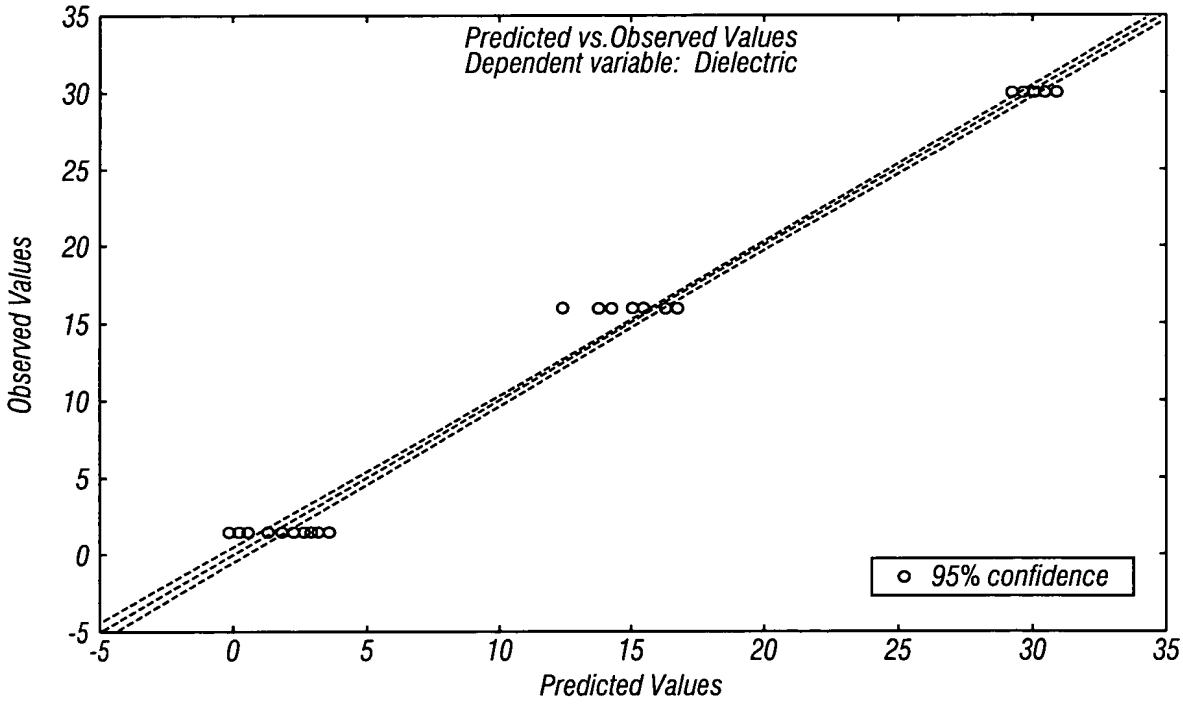

FIG. 8A

Dielectric Constant

Regression Summary for Dependent Variable: Dielectric (Synthetic Impedance Data.sta)
R= .99943711 R = .99887453 Adjusted R^2 = .99878328
F(6,74)=10946. p<0.0000 Std. Error of estimate: .40840

	Beta	Std. Err.	B	Std. Err.	t(74)	p-level
Intercept			-7.53	1.2377	-6.0807	4.808670E-08
AvgD1	0.66643	0.016800	36687.94	924.8812	39.6677	0.000000E+00
1/AvgD1	-0.197847	0.007860	-0.000163	0.000006	-25.1721	0.000000
Cub_Avg	2.44530	0.154098	9224.32	581.2968	15.8685	1.592333E-25
Sqr_Min	-3.33853	0.285158	-2720.66	232.3839	-11.7076	1.638646E-18
Min	1.54184	0.134232	304.33	26.4945	11.4864	4.100279E-18
Log(FMx_D1)	-0.01485	0.003953	-9.21	2.4350	-3.7556	3.421367E-04

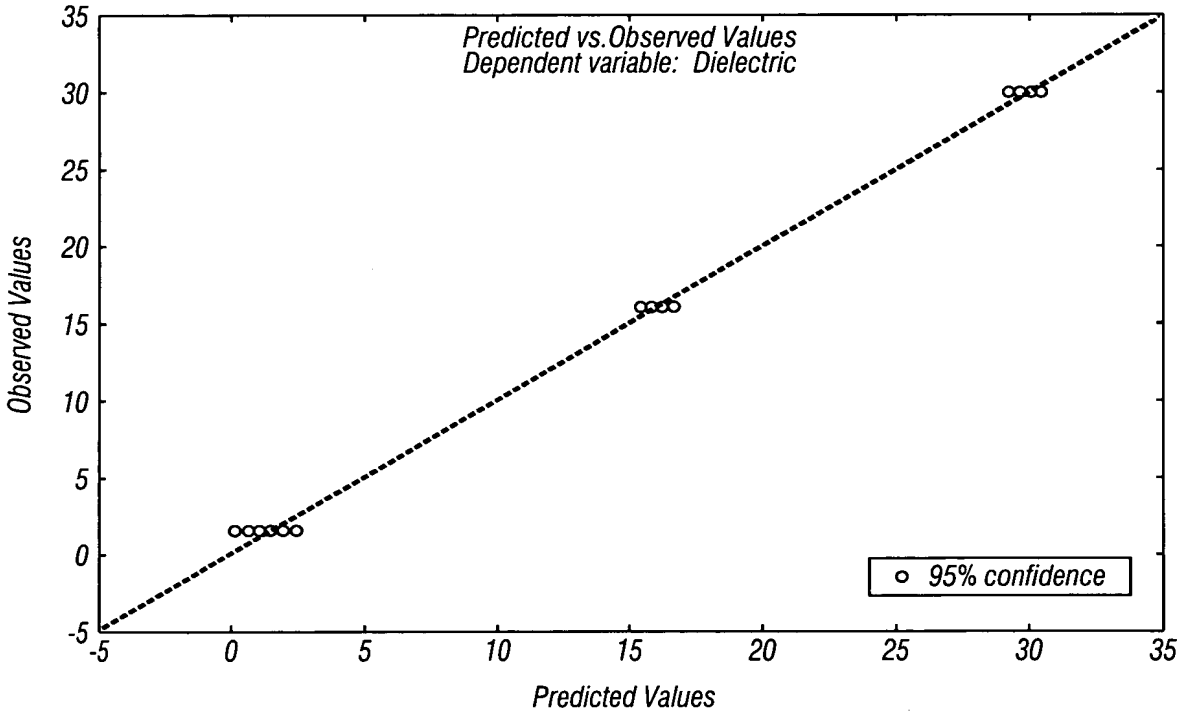

FIG. 8B

Dielectric Constant

Regression Summary for Dependent Variable: Dielectric (Synthetic Impedance Data.sta)
R= .99901744 R^2= .99803585 Adjusted R^2= .99795932
$F(3,77)=13042$. $p<0.0000$ Std. Error of estimate: .52890

	Beta	Std. Err.	B	Std. Err.	t(77)	p-level
Intercept			35.64	1.2392	28.7567	6.24E-43
Cub_Min	0.676927	0.005494	2638.71	21.4159	123.2124	0.00E+00
AvgD1	0.656755	0.010915	36155.19	600.9014	60.1683	0.00E+00
Log(AvgD1)	0.401660	0.011145	10.63	0.2950	36.0399	0.00E+00

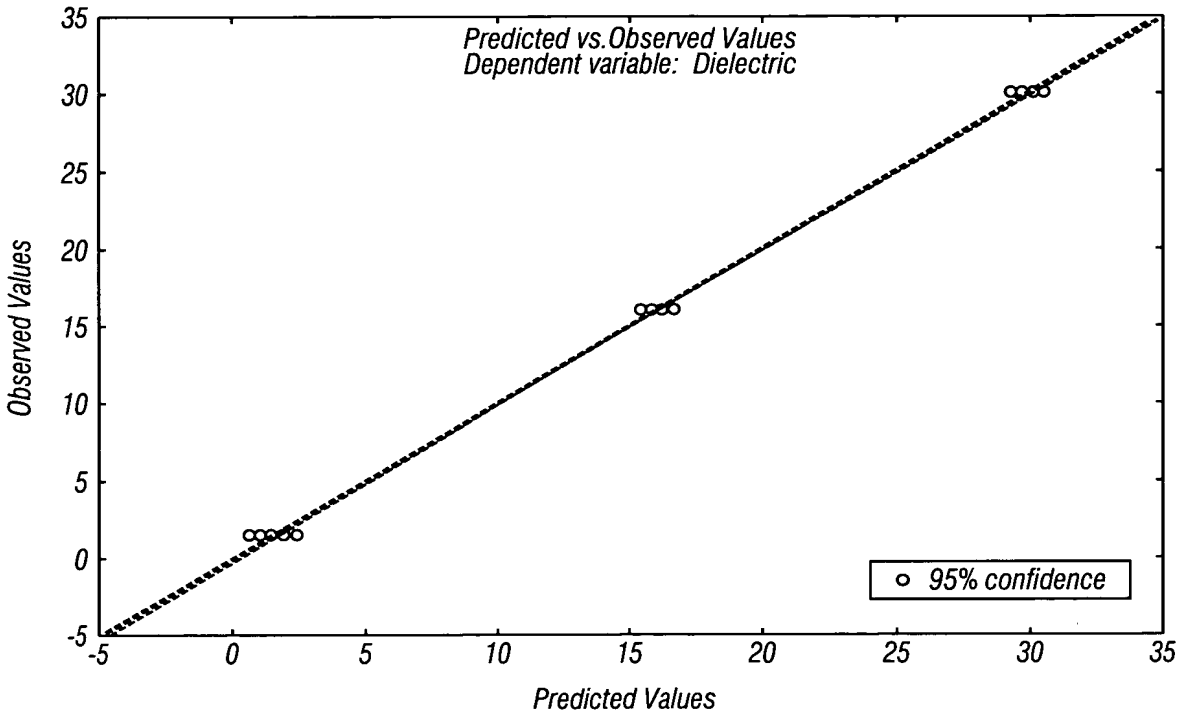

FIG. 8C

Conductivity

*Regression Summary for Dependent Variable: 1/ohm*m (Synthetic Impedance Data.sta)*
R= .99825839 R^2= .99651982 Adjusted R^2= .99633665
F(3,77)=13042. p<0.0000 Std. Error of estimate: .52890

	Beta	Std. Err.	B	Std. Err.	t(76)	p-level
Intercept			0.000112	0.000025	4.3989	3.495104E-05
Max	-3.84661	0.091676	-0.002934	0.000070	-41.9589	0.000000E+00
Min	3.86666	0.064796	0.002932	0.000123	23.9154	4.158121E-37
Cub_Min	0.47895	0.011145	0.007172	0.000970	7.3916	1.594179E-10
Log(Min)	0.37400	0.089062	0.000063	0.000015	4.1993	7.204409E-05

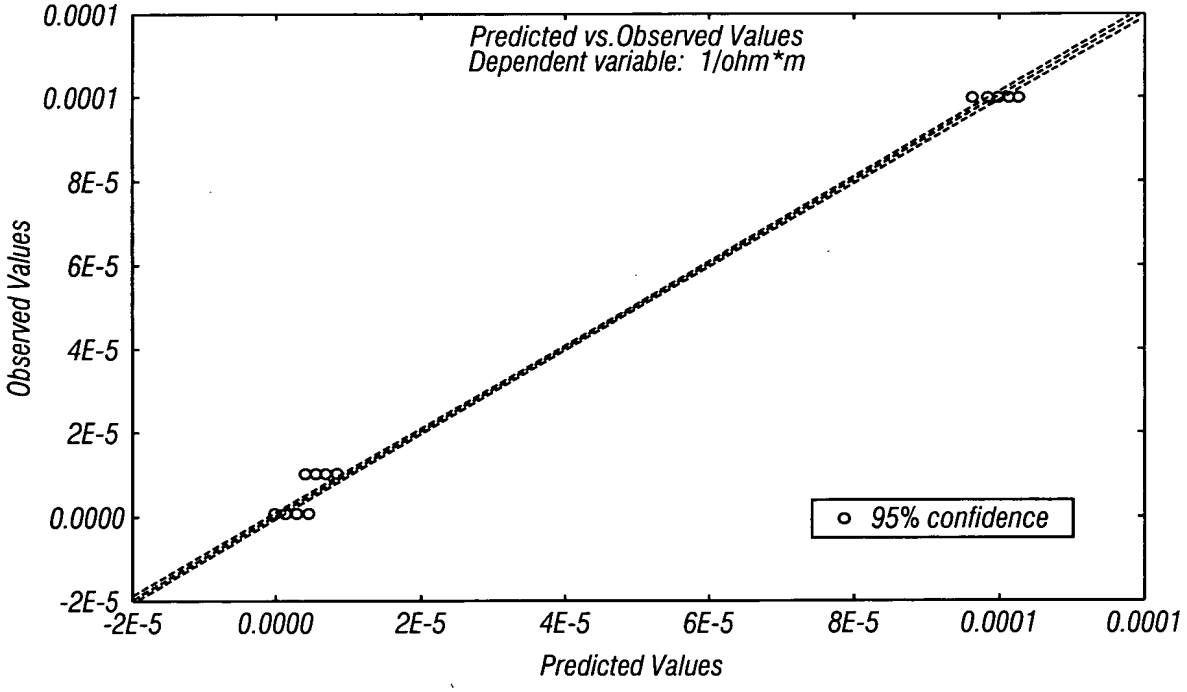

FIG. 8D

Some Definitions of Variables	
Min	Minimum Impedance in Spectrum
Max	Maximum Impedance in Spectrum
Avg	Average Impedance in Spectrum
PK	Frequency of 1st Derivative Minimum Value (an inverted PeaK)
Sqr_	Square_of_
Cub_	Cube_of_
Log( )	Log 10 of
1/	Reciprocal of
D1	First Derivative of Impedance vs Frequency
D2	Second Derivative of Impedance vs Frequency
D3	Third Derivative of Impedance vs Frequency
MinD1=	Minimum of First Derivative of Impedance in Spectrum
MaxD1=	Maximum of First Derivative of Impedance in Spectrum
MinD2=	Minimum of Second Derivative of Impedance in Spectrum
MaxD2=	Maximum of Second Derivative of Impedance in Spectrum
1/FMn_D1	Reciprocal of Frequency of Minimum D1 (Inverted Peak)
1/FMx_D1	Reciprocal of Frequency of Minimum D1
FreqAtMinD1	Frequency of Minimum D1 (Inverted Peak)
FreqAtMaxD1	Frequency of Minimum D1 (May pick up small bump on either side of Inverted Peak)
FreqAtMinD2	Frequency of Minimum D2
FreqAtMaxD2	Frequency of Maximum D2
FreqAtMinD3	Frequency of Minimum D3
FreqAtMaxD3	Frequency of Maximum D3
FreqLMaxD1=	Frequency of LEFT Maximum D1 (Left of Inverted Peak)
FreqRMaxD1=	Frequency of RIGHT Maximum D1 (Left of Inverted Peak)
FreqLZeroD1=FLZD1 =	Frequency of LEFT Zero D1 (Left X-axis Crossing Point)
FreqRZeroD1=FLZD1 =	Frequency of RIGHT Zero D1 (Right X-axis Crossing Point)

FIG. 8E

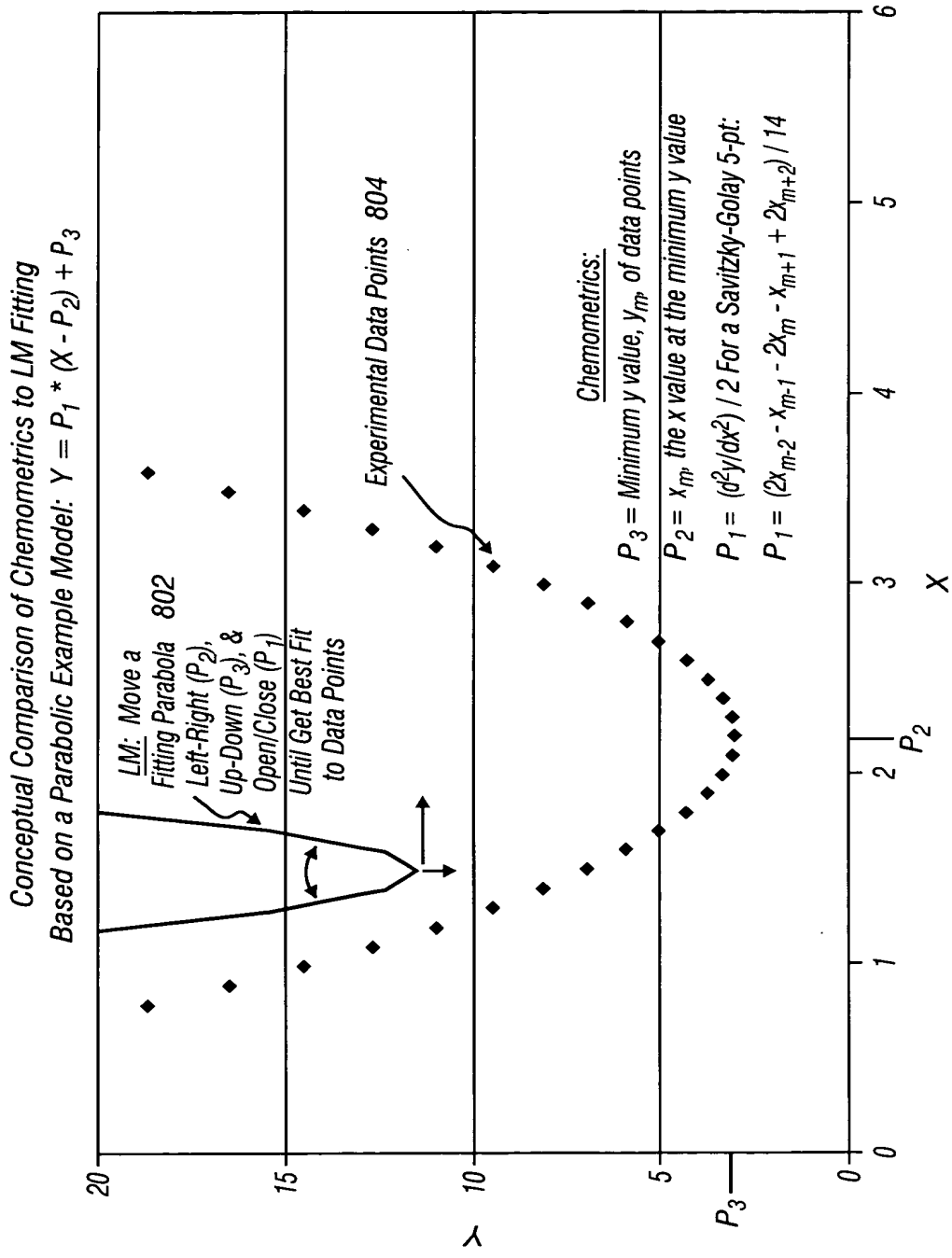
Conceptual Comparison of Chemometrics to LM Fitting
Based on a Parabolic Example Model: Y = P1 * (X - P2) + P3
LM: Move a Fitting Parabola 802
Left-Right (P2),
Up-Down (P3), &
Open/Close (P1)
Until Get Best Fit to Data Points
Experimental Data Points 804
Chemometrics:
P3 = Minimum y value, ym, of data points
P2 = xm, the x value at the minimum y value
P1 = (d2y/dx2) / 2 For a Savitzky-Golay 5-pt:
P1 = (2xm-2 - xm-1 - 2xm - xm+1 + 2xm+2) / 14
Y
X
P3
P2
0
5
10
15
20
1
2
3
4
5
6

FIG. 9

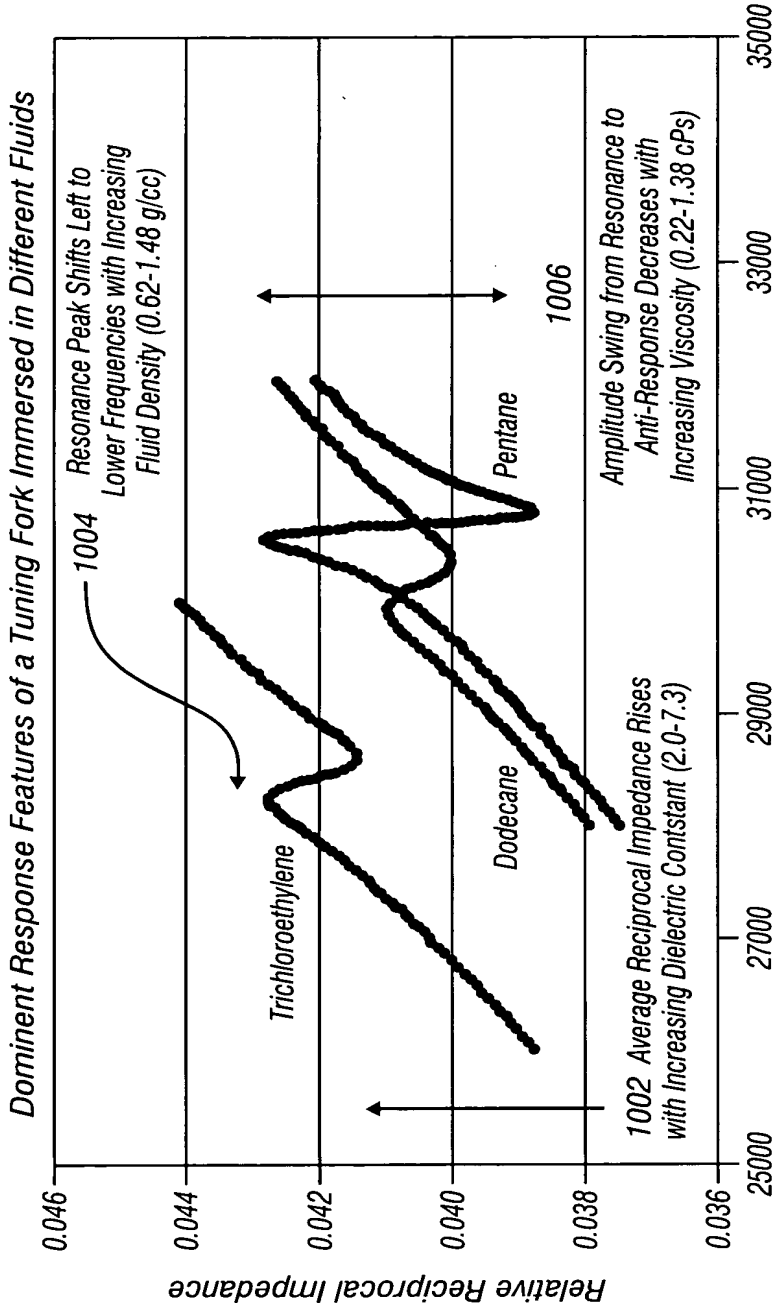
Dominent Response Features of a Tuning Fork Immersed in Different Fluids
1004
Resonance Peak Shifts Left to Lower Frequencies with Increasing Fluid Density (0.62-1.48 g/cc)
Trichloroethylene
Dodecane
Pentane
1006
Amplitude Swing from Resonance to Anti-Response Decreases with Increasing Viscosity (0.22-1.38 cPs)
1002 Average Reciprocal Impedance Rises with Increasing Dielectric Contstant (2.0-7.3)
Relative Reciprocal Impedance
0.046
0.044
0.042
0.040
0.038
0.036
25000
27000
29000
31000
33000
35000
Frequency (Hz)

FIG. 10

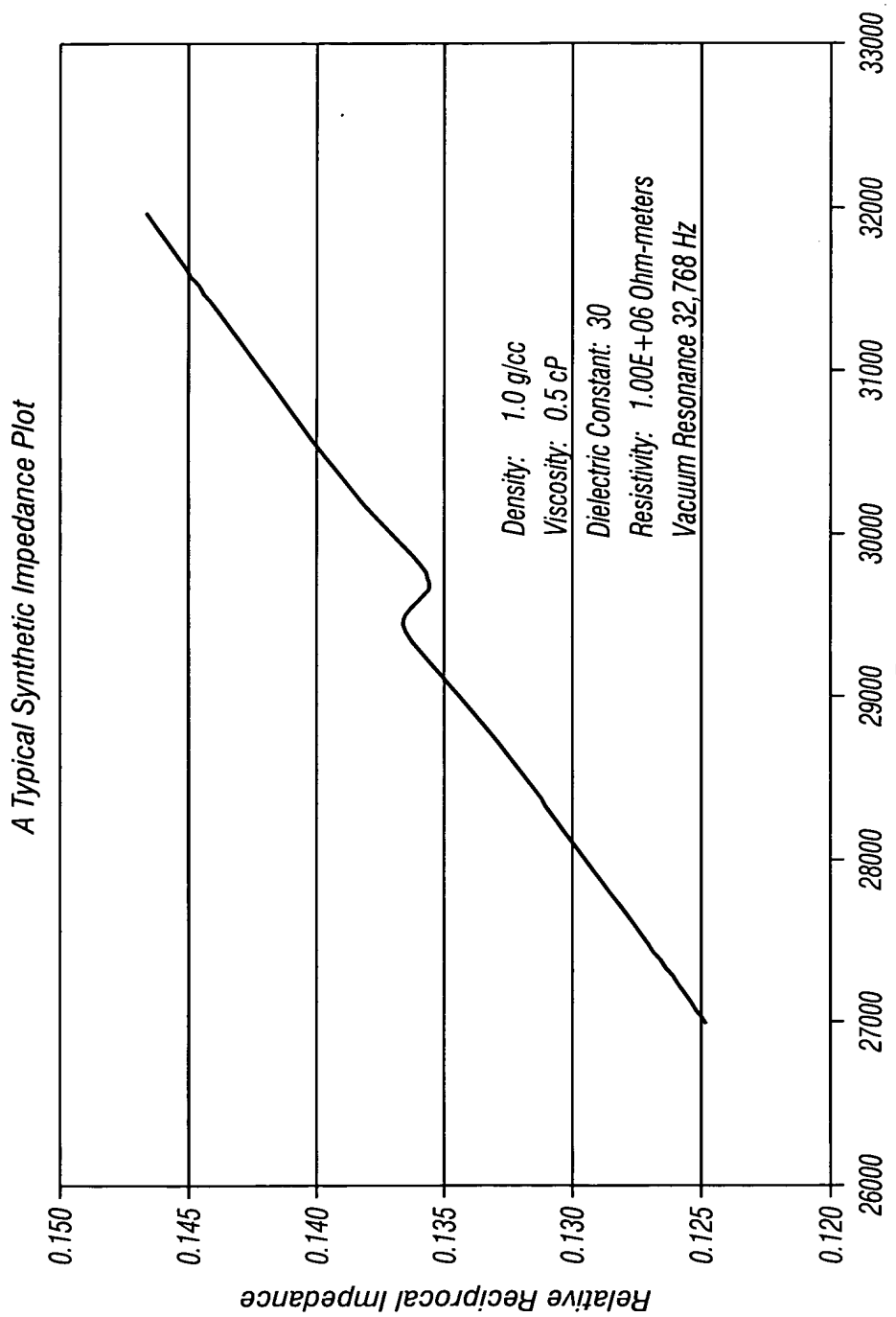
A Typical Synthetic Impedance Plot
Density: 1.0 g/cc
Viscosity: 0.5 cP
Dielectric Constant: 30
Resistivity: 1.00E+06 Ohm-meters
Vacuum Resonance 32,768 Hz
Relative Reciprocal Impedance
0.150
0.145
0.140
0.135
0.130
0.125
0.120
26000
27000
28000
29000
30000
31000
32000
33000
Frequency

FIG. 11

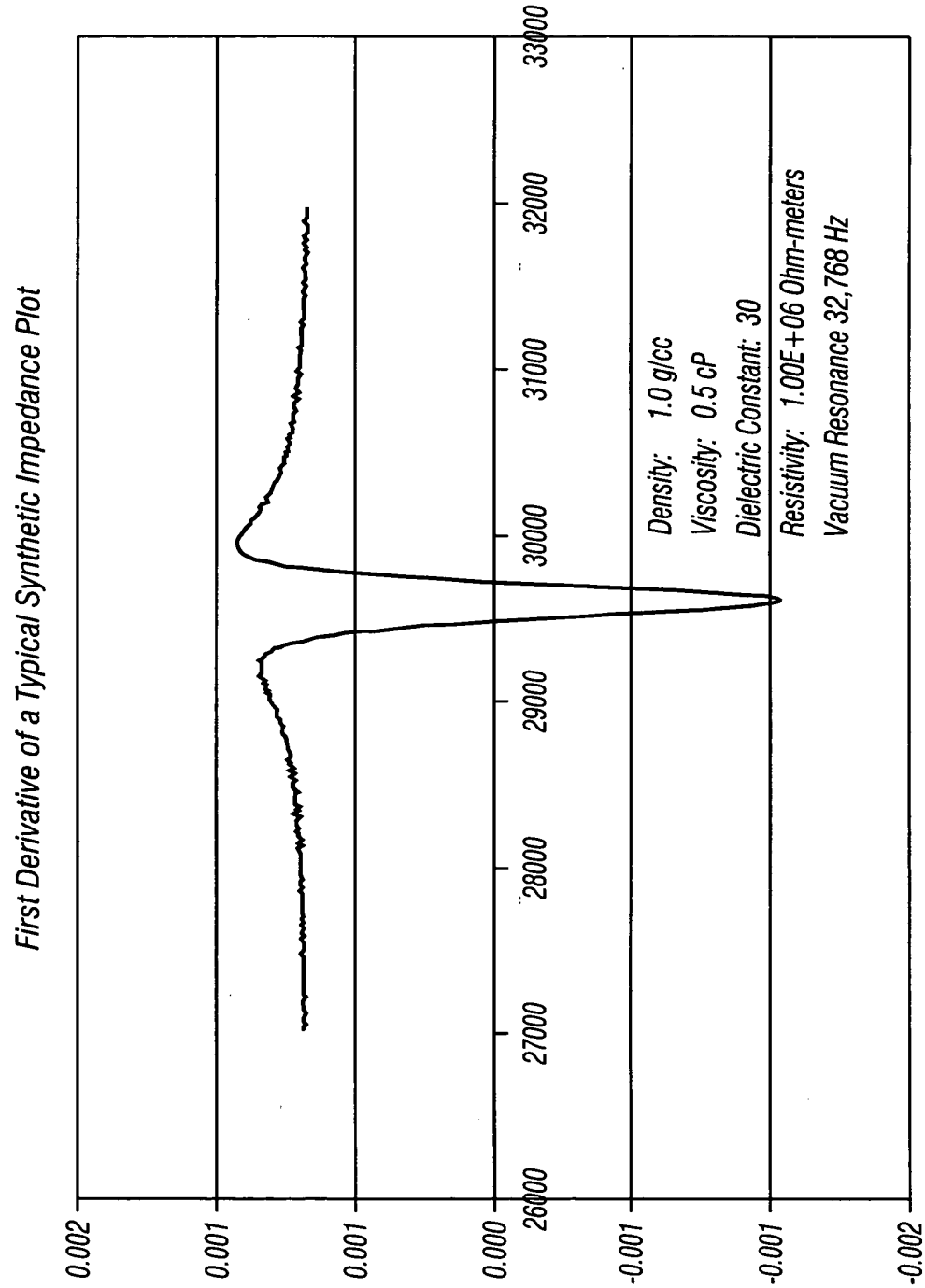
First Derivative of a Typical Synthetic Impedance Plot
0.002
0.001
0.001
0.000
-0.001
-0.001
-0.002
26000
27000
28000
29000
30000
31000
32000
33000
Frequency
Density: 1.0 g/cc
Viscosity: 0.5 cP
Dielectric Constant: 30
Resistivity: 1.00E+06 Ohm-meters
Vacuum Resonance 32,768 Hz

FIG. 12

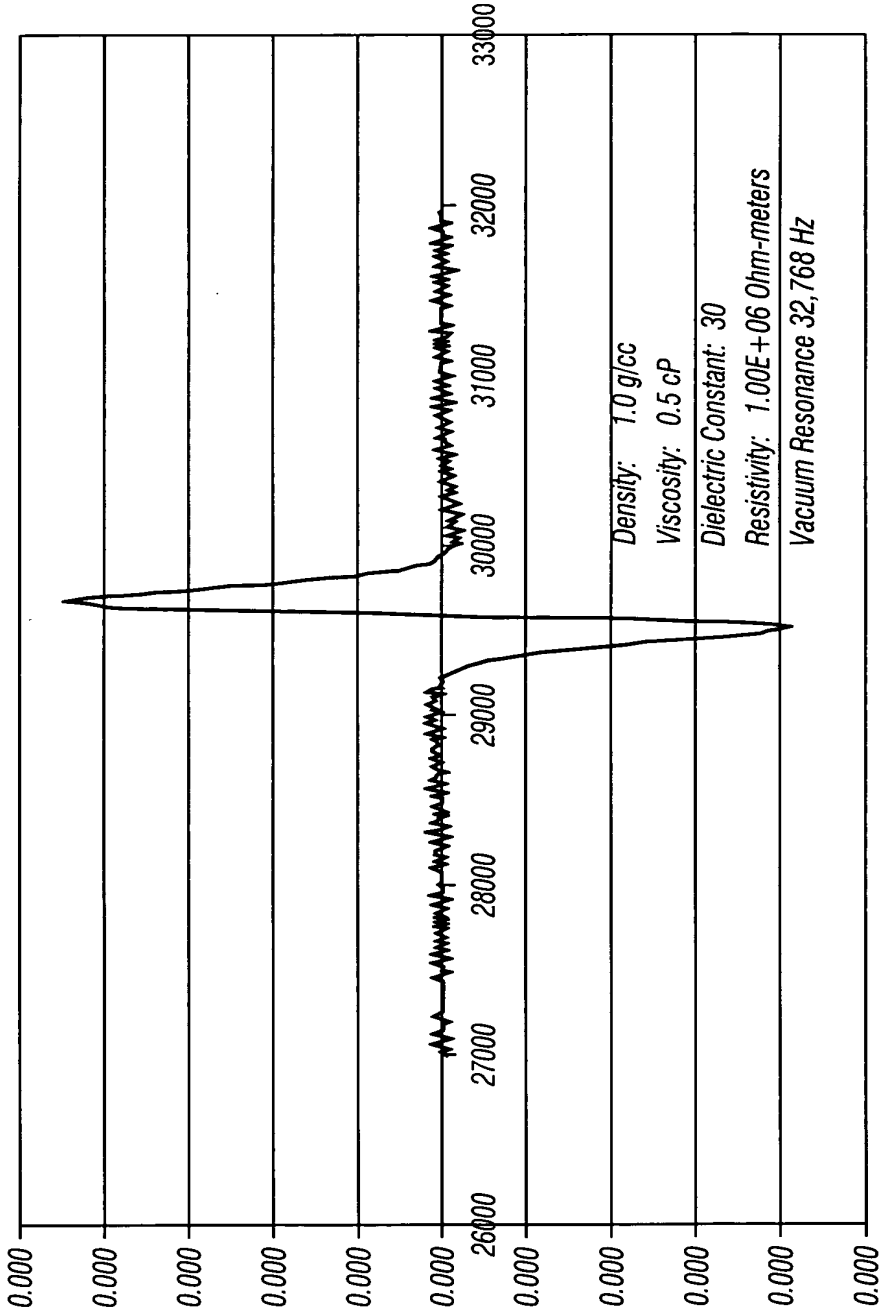
Density: 1.0 g/cc
Viscosity: 0.5 cP
Dielectric Constant: 30
Resistivity: 1.00E+06 Ohm-meters
Vacuum Resonance 32,768 Hz
26000
27000
28000
29000
30000
31000
32000
33000
0.000
Frequency

FIG. 13